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SUMMARY

An experimental flight investigation has been conducted to determine the dynamic lateral stability and control characteristics of a remotely controlled 1/4-scale model of the VZ-2 tilt-wing vertical-take-off-and-landing aircraft. The model was equipped with a full-span slotted flap and a Krueger type nose flap. The investigation included both level-flight and descent conditions over the transition range where wing stalling occurred.

Flight tests of the model in the flaps-retracted configuration indicated that the model had poor lateral flight characteristics in level flight and that these characteristics became worse during descent. These poor lateral characteristics generally consisted of wing dropping and erratic large-amplitude yawing motions normally associated with wing stall. The full-span slotted flap and the Krueger type nose flap when used in combination resulted in large improvements in lateral flight characteristics in both level and descent flights. When the two types of flaps were used separately the lateral flight characteristics did not improve as much as when the flaps were used in combination. Of the two types of flaps, the full-span slotted flap produced the greatest improvement in lateral flight characteristics. Use of the full-span slotted flap, however, caused a considerable reduction in longitudinal flight characteristics. When the mode of propeller rotation was such that the blades were going upward at the wing tips the wing-dropping tendency was worse but the yawing characteristics were better than when the blades were going downward at the wing tips.

INTRODUCTION

Flight tests of the original VZ-2 tilt-wing vertical-take-off-and-landing (VTOL) aircraft, described in reference 1, showed that the aircraft had unacceptable lateral stability and control characteristics in the transition flight conditions in a speed range of approximately 40 to 70 knots which corresponded to a range of wing incidence from approximately 45° to 25°. The difficulties resulted from wing stalling and were more severe for descent conditions than for level-flight or climb conditions. The use of a wing-section modification consisting of a modest amount of leading-edge droop and an increase in nose radius was found to relieve the lateral stability and control troubles to a considerable extent.

The tendency toward wing stall in the transition range for tilt-wing VTOL aircraft had been recognized from wind-tunnel tests as pointed out in references 2 to 4. The effect of this stalling on the lift, drag, and power required, and, consequently, on short-take-off-and-landing (STOL) and engine-out performance had been appreciated for some time. The use of high-lift devices, both trailing-edge flaps and leading-edge devices, had been recommended to relieve the wing stalling by increasing the lifting capability of the wing. With the use of these high-lift devices, the wing can produce more of the lift required of the wing-propeller system and thereby reduce the angle of attack of the wing-propeller combination as explained in detail in reference 4. As a result of this wind-tunnel work the aircraft was modified by the addition of a large flap to determine the effect of such a flap on the lateral handling qualities in the transition range.

The significance of the wing stalling on handling qualities had not been fully appreciated until the flight tests were made; nor had it been recognized in free-flight model tests of tilt-wing VTOL aircraft, even in tests of a model of the VZ-2 reported in reference 5. In the VZ-2 model tests, erratic yawing motions in transition had been noted but had been attributed only to low directional stability. The fact that the lateral stability and control troubles caused by wing stalling had not been fully appreciated in the free-flight model tests might have resulted from the fact that the model had been flown only in level flight where the range of unacceptable behavior occurred over a range of only about 7° wing incidence and from the fact that the model had passed through this range in 3 or 4 seconds in the process of making the transition from hovering to normal forward flight and had not been flown for protracted periods of time in this range.

As a result of the foregoing experience, an investigation has been made with the 1/4-scale free-flight model of the VZ-2 used in the previous investigations of references 5 to 10 to determine: first, if, upon close examination of the range of flight conditions in which the lateral stability and control difficulties associated with stalling had been observed in flight, the same objectionable characteristics could be observed with a free-flight model; and, second, if the difficulties could be recognized, whether the characteristics would be improved by the use of the wing flaps that were to be installed on the full-scale aircraft as a modification.

One phase of this investigation, reported in reference 11, dealt with results of force tests of the model with a full-span slotted flap, leading-edge droop, and full-span ailerons. The other phase of the investigation, discussed in the present paper, consisted of flight tests of the model with a full-span slotted flap and with and without a full-span Krueger type nose flap. These flight tests included both level flight and simulated descent flight over a range of airspeeds in which wing stalling might be expected to occur. The simulation of the descent conditions where the wing stalling had been found to cause the most objectionable handling qualities in the full-scale flight tests required the development of a new free-flight model test technique which is described herein. The research results were obtained mainly from pilots' ratings of the various conditions tested and from motion-picture records of the flights.

SYMBOLS

c	wing chord, ft
i_w	wing incidence, deg
M_α	static longitudinal stability parameter, ft-lb/deg
t	time, sec
V	scaled-up aircraft velocity, knots
α	angle of attack of fuselage, deg
β	angle of sideslip, deg
δ_f	flap deflection, deg
ϕ	angle of roll, deg

APPARATUS AND TESTS

Model

A photograph of the 1/4-scale model of the VZ-2 tilt-wing VTOL aircraft with the full-span flap deflected is shown as figure 1 and a three-view sketch showing the more important dimensions is shown as figure 2. During some of the tests the model was equipped with a full-span Krueger type nose flap, the details of which are given in figure 3. Tables I and II give the geometric and mass characteristics of the model. The geometric changes which have been made to the original VZ-2 model to simulate the full-scale aircraft in its present modified configuration can be readily seen by comparing figure 2 and table I of the present paper with figure 1 and table I of reference 10. For the purpose of this paper, the main change was the installation of the full-span slotted flap which resulted in a 10-percent increase in the wing chord when the flap was in the retracted position. The model had two three-blade propellers with flapping hinges and was powered by a 6-horsepower pneumatic motor which drove the propellers through shafting and right-angle gear boxes. The speed of the motor was changed to vary the thrust of the propellers. Longitudinal control was obtained by a jet reaction control at the rear of the fuselage. Lateral control was obtained by varying the pitch of the propellers differentially and no separate directional control was used.

The controls were deflected by flicker-type (full-on or full-off) pneumatic actuators which were remotely operated by the pilots by means of solenoid-operated valves. The control actuators were equipped with integrating-type trimmers which trimmed the controls a small amount each time a control was applied. With actuators of this type, a model becomes accurately trimmed after flying a short time in a given flight condition.

Test Setup and Equipment

The test setup used in the transition flight tests in the Langley full-scale tunnel was essentially the same as that illustrated by the sketch shown in figure 4. The power for the wing-tilting motor and electric control solenoids was supplied through wires, and the air for the main propulsion motor, the control actuators, and tail control jet was supplied through flexible plastic tubes. These wires and tubes were suspended from above and taped to a safety cable (1/16-inch braided aircraft cable) from a point about 15 feet above the model down to the model itself. The safety cable, which was attached to the fuselage near the center of gravity, was used to prevent crashes in the event of a control failure or in the event that the pilots lost control of the model. During flight, the cable was kept slack so that it did not appreciably influence the motions of the model. Separate pilots controlled the model laterally and longitudinally, since it had been found that if a single pilot operated all controls, he was so busy controlling the model that he had difficulty in ascertaining the stability and control characteristics of the model about its various axes.

In order to simulate descent-flight conditions the model was equipped with an auxiliary compressed-air jet exhausting rearward from the rear of the fuselage. This auxiliary jet thrust enabled the model to be flown in steady level flight with the higher wing incidences and lower propeller thrust settings that would normally correspond to descent conditions. Figure 5 illustrates the balance of forces obtained in the actual descent and simulated descent flights. In actual descent flight (fig. 5(a)), equilibrium is obtained when the flight path is inclined downward to the angle at which the forward component of the weight balances the drag and the normal component of the weight balances the lift. In order to simulate this condition aerodynamically in flight tests in the full-scale tunnel where the airstream is always horizontal, it is necessary to fly the model at the same lift and same drag. In order to obtain equilibrium for this condition a thrust force must be added as shown in figure 5(b). In the present tests this thrust was added by an auxiliary compressed-air jet exhausting from the rear of the model so that it has a minimum effect on the aerodynamics of the model.

This simple representation of the descent condition is valid only for small descent angles where the cosine of the descent angle is approximately equal to one. In order to obtain simulation for large descent angles it would be necessary to incline the jet thrust vector to the flight direction in such a way as to compensate for the fact that the lift should, in truth, be equal only to the normal component of the weight as shown in figure 5(a).

Tests

Flight tests were made to determine the dynamic stability and control characteristics of the model at the intermediate transition speeds which corresponded to full-scale speeds of 37, 44, 50, 57, and 65 knots for the flaps-retracted configuration and 37, 44, and 57 knots for the flaps-deflected configurations. At each of these airspeeds the model was flown in steady level flight with the fuselage at $\alpha = 0^{\circ}$ and in simulated descent conditions at rates of descent which corresponded to full-scale values between 760 and 1000 feet per minute. These tests were made for the flaps-retracted configuration, for a configuration with the full-span slotted flap set at 40° deflection, and for each of these configurations with a full-span Krueger type nose flap set at 115° deflection.

In all the tests, lateral control was obtained by varying the pitch of the propellers differentially $\pm 1\frac{1}{2}^{\circ}$. No separate yaw control was used because at these wing incidences the variable pitch propellers gave approximately the correct amount of rolling moment and yawing moment for coordinated control. Longitudinal control was obtained by a jet reaction control at the rear of the fuselage with a control force of ±5.0 percent of the model weight.

The center of gravity for these tests was 5.4 percent chord ahead of the pivot when the wing was in the hovering flight position (86° incidence). The center of gravity moved as the wing was tilted approximately as shown in reference 11.

The investigation consisted primarily of tests made to study the lateral characteristics of the VZ-2 aircraft in the wing stall region, but some data and observations of the longitudinal stability and trim characteristics were obtained in the process. The flight test results were primarily in the form of qualitative ratings of flight behavior based on pilot opinion. For the lateral stability tests, however, motion-picture records were used to verify and correlate the ratings for the different flight conditions and a few time histories of the model motions have been read from the motion-picture records.

RESULTS AND DISCUSSION

Rating System

A pilot rating system has been used for many years as a means of expressing the results of free-flight model tests which are largely in the form of pilot opinion, as shown in reference 12. The ratings were expressed in terms of letters (A, B, C, and D with + and - signs used for finer graduation) and they were described only as "good, fair, poor, and unflyable."

As a result of the wide acceptance of the Cooper pilot-opinion rating system in full-scale flight test work, an attempt has been made in the present investigation to adjust the flying-model pilot rating system to conform with the Cooper rating system described in reference 13. This change has involved the use of a numerical rating scale and more detailed description of the rating.

This revised flying model pilot rating system is shown in table III where it is compared with the Cooper rating system. The intent of the model ratings is to consider the behavior of the model that would represent the behavior required of an aircraft to meet all the conditions given for the Cooper rating system - that is, whether the mission could be accomplished, the aircraft landed, and the aircraft acceptable for normal operating conditions or emergency conditions, and so forth. The ratings for the model are limited to the stability and control aspects of flying qualities since the remote control pilot is unable to sense buffeting and other factors that affect the ratings of the pilot in a full-scale aircraft. The description of the model ratings differs from that of the Cooper ratings because of the pilot not being in the model, the dynamic effects of the small scale of the model, differences in piloting technique, the limited maneuvers that can be performed with the model, and the limited task assigned to the pilot of the model.

An indication of how well pilot ratings obtained with a flying model correlate with ratings for a full-scale aircraft might be obtained from figure 6 which shows the pilot ratings for the present VZ-2 flying model superimposed on the flying-qualities boundaries obtained in flight tests of the full-scale airplane as reported in reference 14.

The model ratings presented in figure 6 show that for the level-flight test condition, in the range of velocities where the aircraft exhibited wing stall problems, the model had poor lateral flight behavior with its worst flight behavior at approximately 58 knots. This result agrees with the full-scale flight test results that showed in level flight the rate of descent boundary or the worst flight behavior region extended from approximately 54 to 65 knots. In the descent tests between 760 and 1000 ft/min all the ratings indicated worsening flight behavior as would be expected from the expanded rate of descent boundary. At the lower airspeeds the excursions in yaw tended to become larger and as a result greatly influenced the establishment of the overall ratings. It is felt that if a separate yaw control had been used in an effort to minimize these extremely large motions these ratings could possibly have been improved. It may be noted that in the region within the rate of descent boundary the flying model ratings did not indicate as severe lateral problems as those indicated for the aircraft by the unacceptable dangerous region (approximately a Cooper pilot rating of 8). The poorer flight behavior ratings for the aircraft may have been the result of the severe buffeting in this region which in turn influenced the pilots' ratings. This buffeting could not be observed or evaluated in the model rating because of the pilot's remote location.

Other than this inability to observe and evaluate the buffeting problem, the results of these model tests for both level and descent flight in the wing stall region appeared to be quite similar to the aircraft. The unacceptable lateral flight behavior in both cases was characterized by intermittent wing dropping and wide and erratic excursions in yaw (sideslip).

It should be noted that the full-scale flying-qualities boundaries shown in figure 6 were for the VZ-2 aircraft in its original configuration, whereas the model ratings are for the present modified model. Figure 7 shows a comparison of the results of tuft tests made with the original full-scale aircraft (ref. 15) and tuft tests made with the present model with the full-span slotted flap installed in the retracted position which resulted in a 10-percent increase in the chord of the wing. The flow patterns of figure 7 show the same gross effect, for both the aircraft and model, of good flow over the outboard wing sections and large areas of disturbed or stalled flow between the nacelles. Although these areas do not agree in detail, both the aircraft and model experienced unsymmetrical stalling over the same general areas and seem to correlate with the fact that the handling qualities were generally similar.

Presentation of Model Results

All the parameters used in this flight investigation have been scaled up to a full-scale airplane weight of 3450 pounds. The results of the model tests to determine the effects of modifications to the basic configuration are presented in the form of bar graphs of the pilots' ratings of each test condition. For this presentation the pilot has separately rated the two most predominate lateral characteristics found in both the model and the full-scale tests of the VZ-2 in the wing stall flight range. These characteristics were the tendency of the model to have an intermittent wing dropping and the tendency of the model to undergo wide erratic excursions in yaw (sideslip) and changes in trim in yaw. In order to supplement these pilot ratings and to illustrate the model motions, representative time histories have been read from the motion-picture records. These time histories show the rolling and yawing motions and the pilots' control applications.

Lateral Behavior

Flaps-retracted configuration in level flight.- For the flaps-retracted configuration in level flight, the pilot ratings of figure 8(a) indicate that the model generally had poor flight characteristics throughout the range of airspeed. These poor ratings were the result of a combination of wing dropping at the higher speeds and large erratic yawing motions and changes in yaw trim at the lower speeds. The wing-dropping tendency decreased with decrease in airspeed until at the lowest speed (37 knots) very little attention was required to keep the wings level. This improvement in roll apparently was the result of the less erratic variation of lift on the two wing panels when the wing became more completely stalled at the lower airspeeds. The yawing motions increased as the airspeed decreased until at the lowest airspeed tested almost constant attention was required to keep the model flying. This difficulty in yaw was apparently caused, at least partly, by low or negative directional stability.

Two representative time histories of the model motions are shown in figure 9. The erratic rolling motion of figure 9(b) for a speed of 57 knots illustrates the wing-dropping tendency found at the higher airspeeds; and the large-amplitude yawing motions showing the model trimming from side to side in figure 9(a) for a speed of 37 knots illustrates the wide erratic excursions in yaw and changes in yaw trim.

Flaps-retracted configuration in descent flight.- For the flaps-retracted configuration, pilot ratings of the model behavior for rates of descent between 760 and 1000 feet per minute are shown in figure 8(b). These ratings indicate very poor flight characteristics over the range of airspeeds. For example, at the highest airspeed the wing-dropping tendency made the model very difficult to fly and at the lowest airspeed the yawing tendencies made the model almost unflyable. The pilot felt that there was another factor other than wing stall which contributed to the very poor flight characteristics; this was the weak control which resulted from the low propeller pitch control effectiveness at the reduced engine power settings in descent flight.

When comparing descent with level-flight conditions (fig. 8) both sets of ratings indicate the same general trends of wing dropping and yawing motions with airspeed. The descent tests, however, showed definitely worse characteristics for all conditions tested.

Time histories showing the model motions during descent are presented in figure 10. The much more predominate wing dropping at 57 knots and yawing motions at 37 knots for the descent tests are obvious when compared with the level-flight time histories of figure 9. Another indication of the deterioration of the flight characteristics in descent can be seen by comparing the frequency or amount of control applications. These data indicate that the pilot was required to give two to three times more control in the descent tests than in level flight.

Flaps-deflected configuration in level flight.- The full-span slotted flap was deflected to 40° and a full-span Krueger type nose flap was installed on the model in an effort to reduce the wing stall and improve the model flight characteristics.

Level-flight ratings for this flaps-deflected configuration over the same speed range as that covered for the flaps-retracted configuration are shown in figure 11(a). In general, these ratings indicate that the model had good flight characteristics for all conditions tested. The flaps eliminated any tendency toward wing dropping and wing stall but did not completely eliminate the tendency toward large-amplitude yawing motions. The existence of these yawing motions for the flaps-deflected configuration indicated that the model was directionally unstable as it had been for the flaps-retracted configuration. There were no wind-tunnel force tests to support this conclusion, therefore a few flight tests were made with an additional ventral fin, 1 foot square, located immediately behind the basic ventral fin shown in figure 2. These tests were made at all three speeds normally covered in the tests: 37, 44, and 57 knots. The use of this additional tail greatly reduced the yawing motions and thereby supported the conclusion that the objectionable yawing motions had resulted primarily from poor directional stability.

The improved flight characteristics of the flaps-deflected configuration become very apparent when comparing the time histories of figure 12 with those for the flaps-retracted configuration (fig. 9). The rolling and yawing motions appear much smoother and steadier and the pilots' control applications are less frequent; this indicates that considerably less effort was required to maintain flight than for the flaps-retracted configuration. An example of the ease of flight for the flaps-deflected configuration is shown in figure 12(a) by a fairly long period (approximately 20 seconds) where no control was required.

Flaps-deflected configuration in descent flight.- Flight ratings in figure 11(b) for the rates of descent between 760 and 1000 feet per minute indicate that the flaps-deflected configuration generally had fair flight characteristics. When these results are compared with the ratings for the level flight condition for the same configuration (fig. 11(a)) it can be seen that the model had an increase in wing-dropping tendency at the lower airspeeds. This result indicates that there was some intermittent wing stalling for the flaps-deflected configuration in descent. Further comparison of the flaps-deflected configuration showed increased yawing motions in the descent conditions. This tendency was most apparent at the low airspeed where the model became somewhat difficult to fly.

Comparison of the two configurations during descent in figures 11(b) and 8(b) shows that even though the flaps-deflected configuration exhibited only fair flight characteristics there was still a marked improvement over the flaps-retracted configuration.

Time histories for the flaps-deflected configuration in descent are presented in figure 13. Comparison of these data with those for level flight (fig. 12) shows modest increases in the rolling motions or wing-dropping tendencies and some increase in the erratic nature of the yawing motions at the lowest airspeed.

Comparison of the lateral control for the flaps-deflected and flaps-retracted configurations in descent flight in figures 13 and 10, respectively, shows that much less control was given by the pilot for the flaps-deflected configuration.

Several descent tests were made with the slotted flap and the Krueger type nose flap deflected separately on the model. These tests gave an indication as to which flap contributed the most toward stall alleviation and improvement in flight characteristics. The results of these descent tests are shown in the pilots' ratings of figure 14. From these data it can be seen, that of the two, the full-span slotted flap generally gave better flight characteristics than the full-span Krueger type nose flap. Each flap when used separately gave somewhat worse flight characteristics than those obtained when both flaps were used in combination (fig. 11), but definitely better flight characteristics than the flaps-retracted configuration (fig. 8).

Reversed propeller rotation.- Since there has been some consideration on tilt-wing VTOL aircraft as to the use of propellers rotating in the opposite direction from that shown in figure 2, some brief tests were made to determine the effects of reversed propeller rotation on both the level- and descent-flight characteristics. In the basic configuration the mode of propeller rotation was such that the blades were moving downward at the wing tips. With the reversed rotation the blades were moving upward at the tips. For all conditions tested, which included flights with and without deflection of the full-span slotted flap and the Krueger type nose flap, reversed (up-at-the-tip) propeller rotation generally showed an increased tendency toward wing dropping and an improvement in the poor yaw characteristics. It appears that these differences may be caused by the changes in the angle of attack on the inboard and outboard wing panels resulting from the slipstream rotation. This effect of propeller rotation on local wing angle of attack and consequent stalling is described in detail in reference 16. With the reversed propeller rotation, the slipstream rotation causes the outboard wing section to tend to stall more severely and the inboard wing section to tend to stall less severely than with the original propeller rotation. When this occurs the tendency will be for the wing dropping to be more severe because of the increased distance of the stalled area from the center of gravity, and for the directional stability to be improved because of the better airflow behind the less stalled inboard wing in the region of the vertical tail.

Longitudinal Behavior

As pointed out previously this investigation was carried out primarily to study the lateral flight characteristics of the VZ-2 aircraft in the wing-stall region, but a few observations of the longitudinal stability and trim characteristics were made and are reported in the following paragraph.

Very little difference in the longitudinal characteristics was noticed between level flight and descent flight for any of the configurations tested. Deflection of the full-span slotted flap, however, caused a deterioration in longitudinal flight characteristics and resulted in the model being more difficult to control. Force-tests data taken from reference 11 and plotted in figure 15 substantiate these flight tests results by indicating decreased static longitudinal stability for the flap-deflected configuration. Use of the full-span Krueger type nose flap did not appear to result in any changes in the longitudinal flight characteristics.

CONCLUSIONS

The following conclusions are drawn from the flight investigation of a 1/4-scale flying model of the VZ-2 aircraft over the transition range where wing stalling occurred.

1. With flaps retracted the model had poor lateral flight characteristics in level flight and its behavior became very poor during descent flight.

2. A combination of the full-span slotted flap and Krueger type nose flap resulted in large improvements of the lateral flight characteristics in both level-flight and descent conditions.

3. Either the full-span slotted flap or the Krueger type nose flap used separately improved the lateral flight characteristics but not as much as

the combination of both flaps. Of the two types of flaps the full-span slotted flap gave the most improvement in lateral characteristics.

4. When the propeller rotation was reversed so that the upgoing blades were outboard the wing-dropping tendency became worse and the yawing characteristics improved.

5. The full-span slotted flap caused a deterioration in longitudinal flight characteristics, but the Krueger type nose flap had no apparent effect on the longitudinal flight characteristics.

6. There was very little difference between level-flight and descent conditions as far as longitudinal flight characteristics were concerned.

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TABLE I

GEOMETRIC CHARACTERISTICS OF THE MODEL

Propellers (three blades each):	
Diameter, in.	28
Solidity	0.239
Chord, in.	3.0
Wing:	
Pivot station, percent chord	33.7
Sweepback (leading edge), deg	0
Airfoil section	Modified NACA 4415
Aspect ratio	4.78
Chord, in.	15.63
Taper ratio	1.0
Area, sq in.	1166.5
Span, in.	74.63
Dihedral angle, deg	0
Flap:	
Chord, in.	5.21
Chord, percent c	0.33
Span, in.	32.62
Area, sq in.	169.95
Vertical tail:	
Sweepback (leading edge), deg	28.0
Airfoil section	Modified NACA 0012
Aspect ratio	0.85
Root chord (at top of fuselage), in.	23.0
Tip chord (extended to plane of horizontal tail), in.	14.63
Taper ratio	0.64
Area, sq in.	301.0
Span (from top of fuselage to plane of horizontal tail), in.	16
Rudder (hinge line perpendicular to fuselage center line):	
Chord, in.	5.75
Span, in.	14.44
Area, sq in.	75.7
Horizontal tail:	
Sweepback (leading edge), deg	0
Airfoil section	Modified NACA 0012
Aspect ratio	2.91
Chord, in.	10.19
Center-section chord, in.	12.63
Area (including center body), sq in.	323.7
Span, in.	29.70
Dihedral angle, deg	0
Ventral fin*:	
Chord, in.	9.25
Span, in.	4.0
Area, sq in.	37.0

*Aft end located on model 11.0 in. forward of rudder hinge line measured along bottom of fuselage.

TABLE II

SCALED-UP MASS CHARACTERISTICS OF MODEL

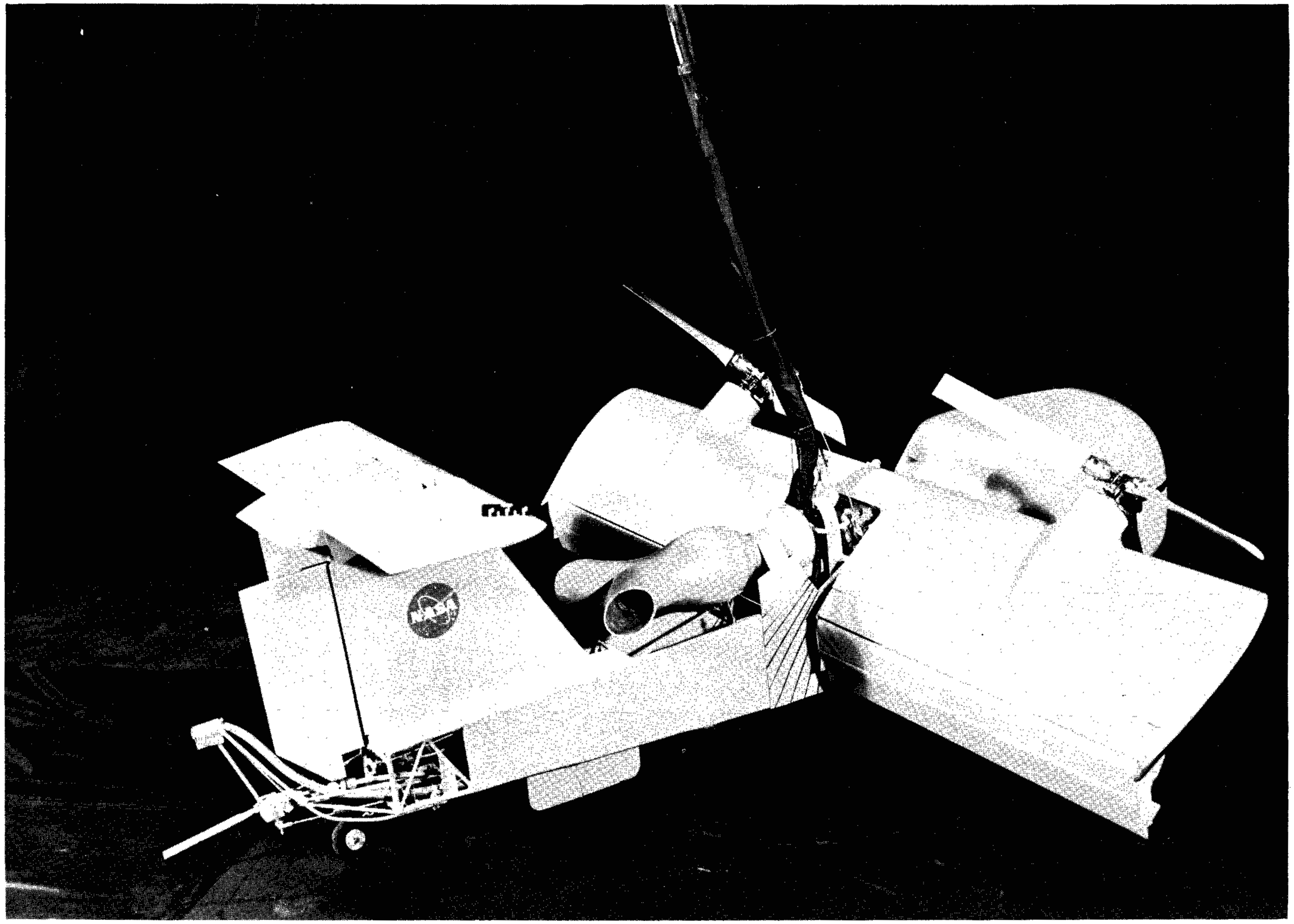
Gross take-off weight (including one pilot and research instrumentation), lb	3,533
Rolling moment of inertia, I_X, slug-ft^2 (hovering configuration)	3,280
Pitching moment of inertia, I_Y, slug-ft^2 (hovering configuration)	3,890
Yawing moment of inertia, I_Z, slug-ft^2 (hovering configuration)	5,330

TABLE III

COMPARISON OF MODEL RATING SYSTEM WITH COOPER RATING SYSTEM

Numerical rating	Flying model pilot rating system	Cooper pilot-opinion rating system				
	Description	Description	Primary mission accomplished	Can be landed	Adjective rating	Operating conditions
1	Extremely easy to fly - requires no attention to control	Excellent, includes optimum	Yes	Yes		
2	Very easy to fly - requires practically no attention to control	Good, pleasant to fly	Yes	Yes	Satisfactory	Normal operation
3	Easy to fly - requires very little attention to control	Satisfactory, but with some mildly unpleasant characteristics	Yes	Yes		
4	Not difficult to fly - requires attention to control	Acceptable, but with unpleasant characteristics	Yes	Yes		
5	Not too difficult to fly - requires considerable attention to control	Unacceptable for normal operation	Doubtful	Yes	Unsatisfactory	Emergency operation
6	Difficult to fly - requires almost constant attention to maintain flight	Acceptable for emergency condition only[1]	Doubtful	Yes		
7	Very difficult to fly - requires constant attention to maintain flight	Unacceptable even for emergency condition[1]	No	Doubtful		
8	Extremely difficult to fly - flyable only with maximum attention given to maintain flight	Unacceptable - dangerous	No	No	Unacceptable	
9	Unflyable - cannot be flown even with maximum attention given to maintaining flight	Unacceptable - uncontrollable	No	No		No operation
10	Catastrophic - model destruction	Motions possibly violent enough to prevent pilot escape	No	No	Catastrophic	

[1]Failure of stability augmenter.



L-61-3172

Figure 1.- Photograph of the 1/4-scale model of the VZ-2 tilt-wing VTOL aircraft with full-span flap and ailerons.

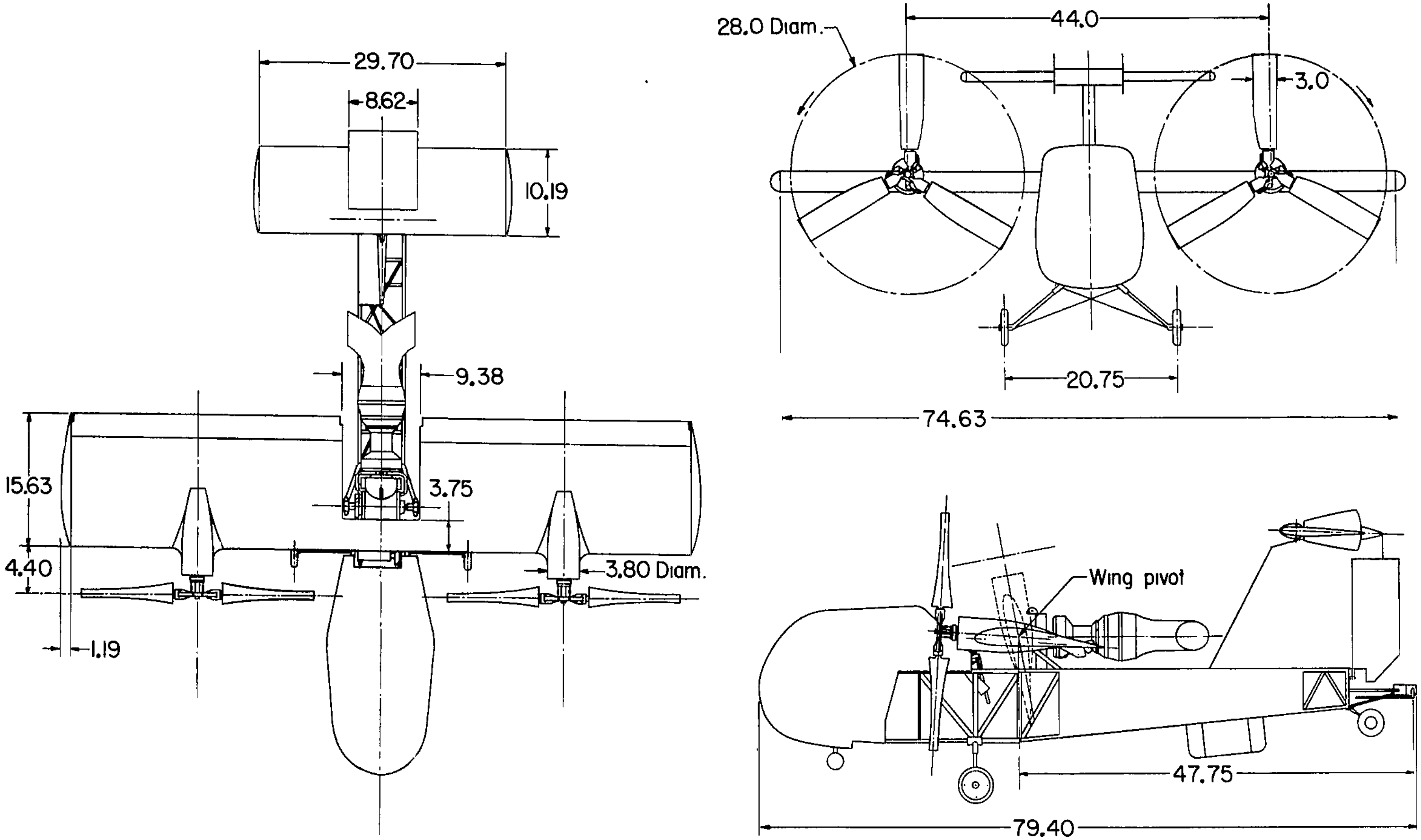
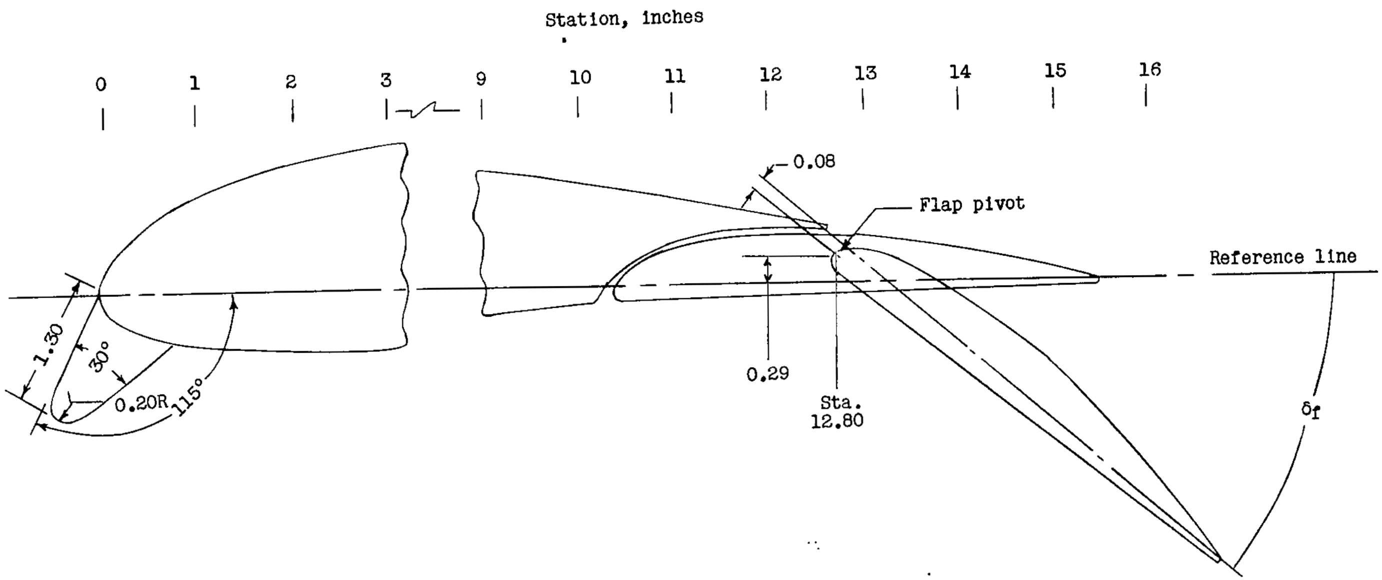


Figure 2.- Three-view sketch of model. All dimensions are in inches.



Airfoil

NACA 4415 airfoil
to station 9.975

Station	Upper	Lower
0.178	0.437	-0.255
.356	.594	-0.353
.713	.818	-0.466
1.069	.985	-0.529
1.425	1.117	-0.567
2.138	1.321	-0.596
2.850	1.461	-0.591
3.562	1.556	-0.567
4.275	1.603	-0.534
5.700	1.603	-0.463
7.125	1.501	-0.388
8.550	1.325	-0.305
9.975	1.087	-0.221
Straight line fairing to		
15.630	.023	-0.023

Slot Contour

Station	Ordinate
9.970	-.221
10.100	-.215
10.200	-.205
10.300	-.140
10.400	+.020
10.500	.135
10.600	.210
10.800	.320
11.000	.390
11.200	.440
11.500	.500
11.800	.535
12.100	.540
Straight line fairing to	
12.800	.520

Flap

Station	Upper	Lower
10.420	-.080	-.080
10.460	+.030	-.140
10.500	.080	-.170
10.600	.160	-.195
10.750	.250	Straight line given under "Airfoil"
11.000	.335	
11.250	.390	
11.750	.450	
12.000	.460	
12.400	.480	
12.680	.485	
12.980	.480	
13.100	.470	
13.300	.450	
13.450	.435	
	Straight line given under "Airfoil"	
15.630	.023	-.023

Figure 3.- Geometric characteristics of wing. All dimensions are in inches.

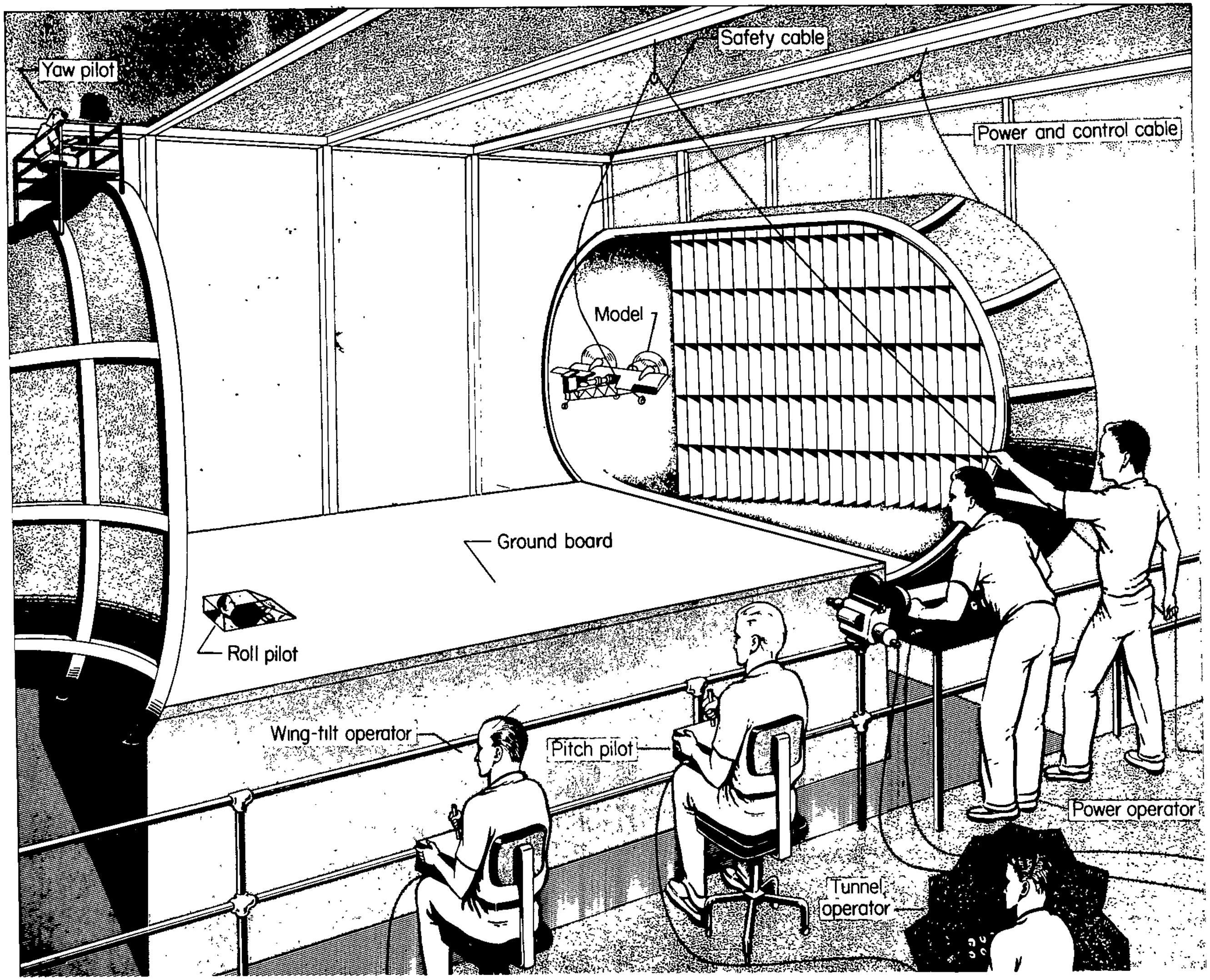
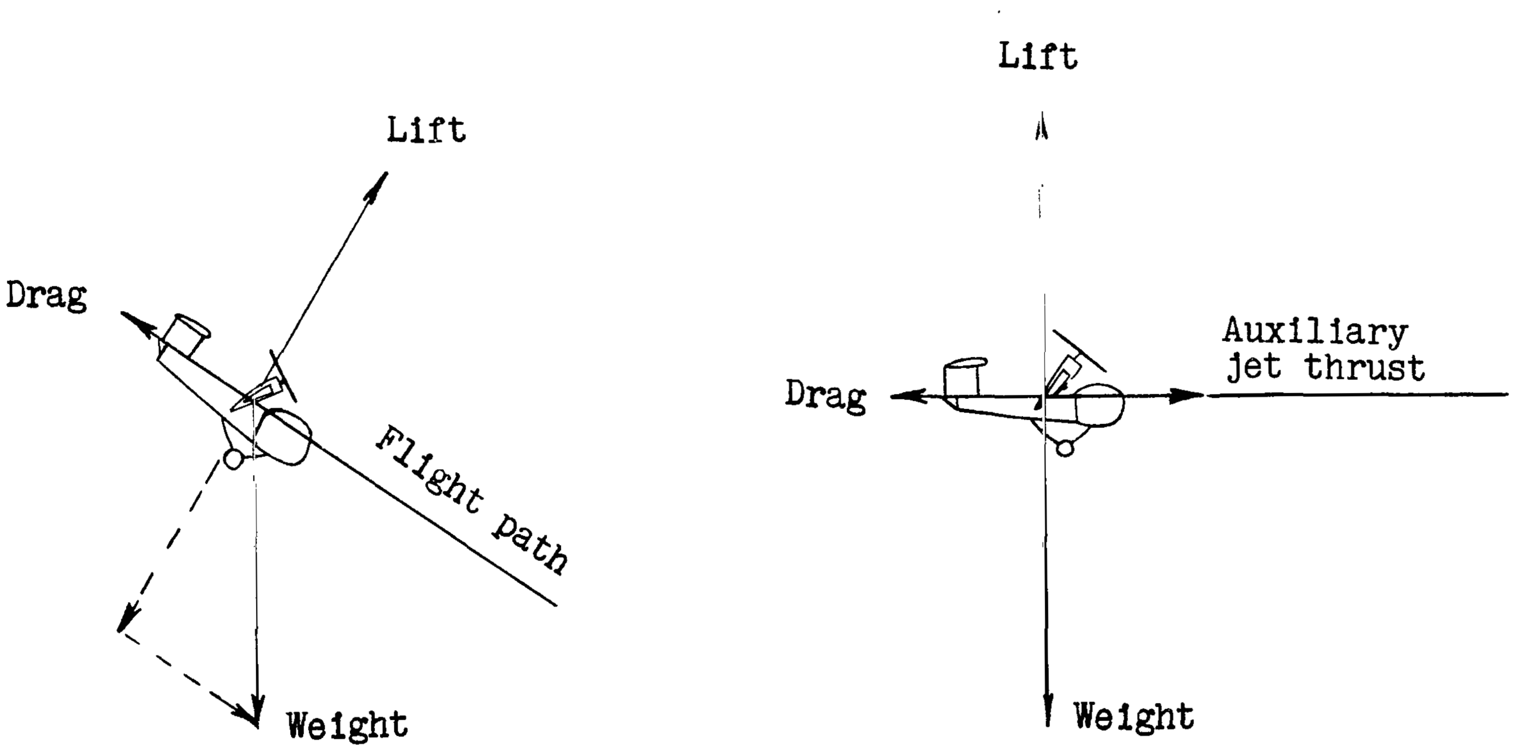


Figure 4.- Sketch of the flight test setup in the Langley full-scale tunnel.



(a) Descent flight.

(b) Simulated descent flight.

Figure 5.- Balance of forces for descent flight and simulated descent flight.

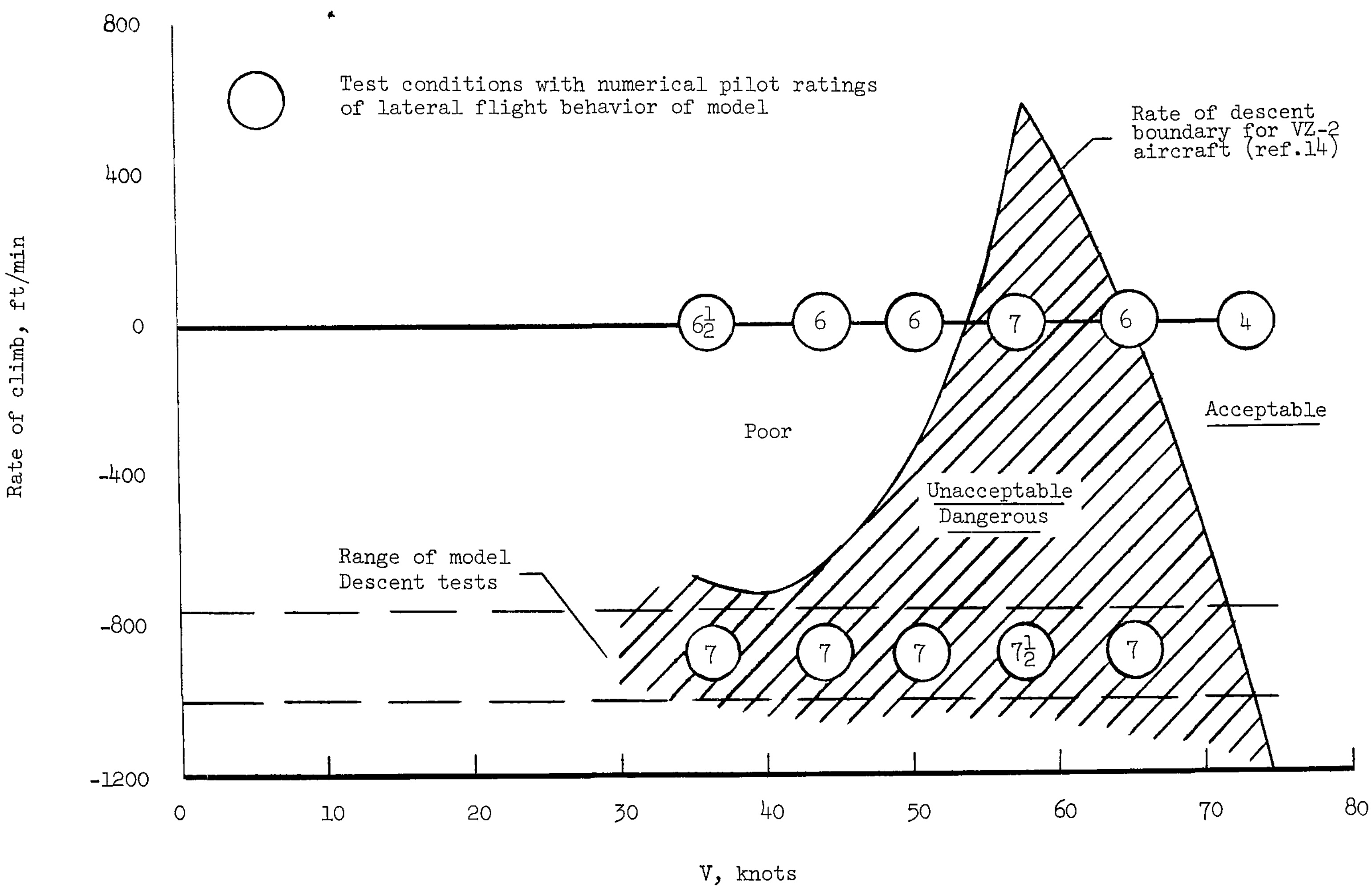


Figure 6.- Rating of the lateral flight behavior of the model for both level and descent flight compared with the flying qualities rate of descent boundary and descriptive ratings for the full-scale VZ-2 aircraft.

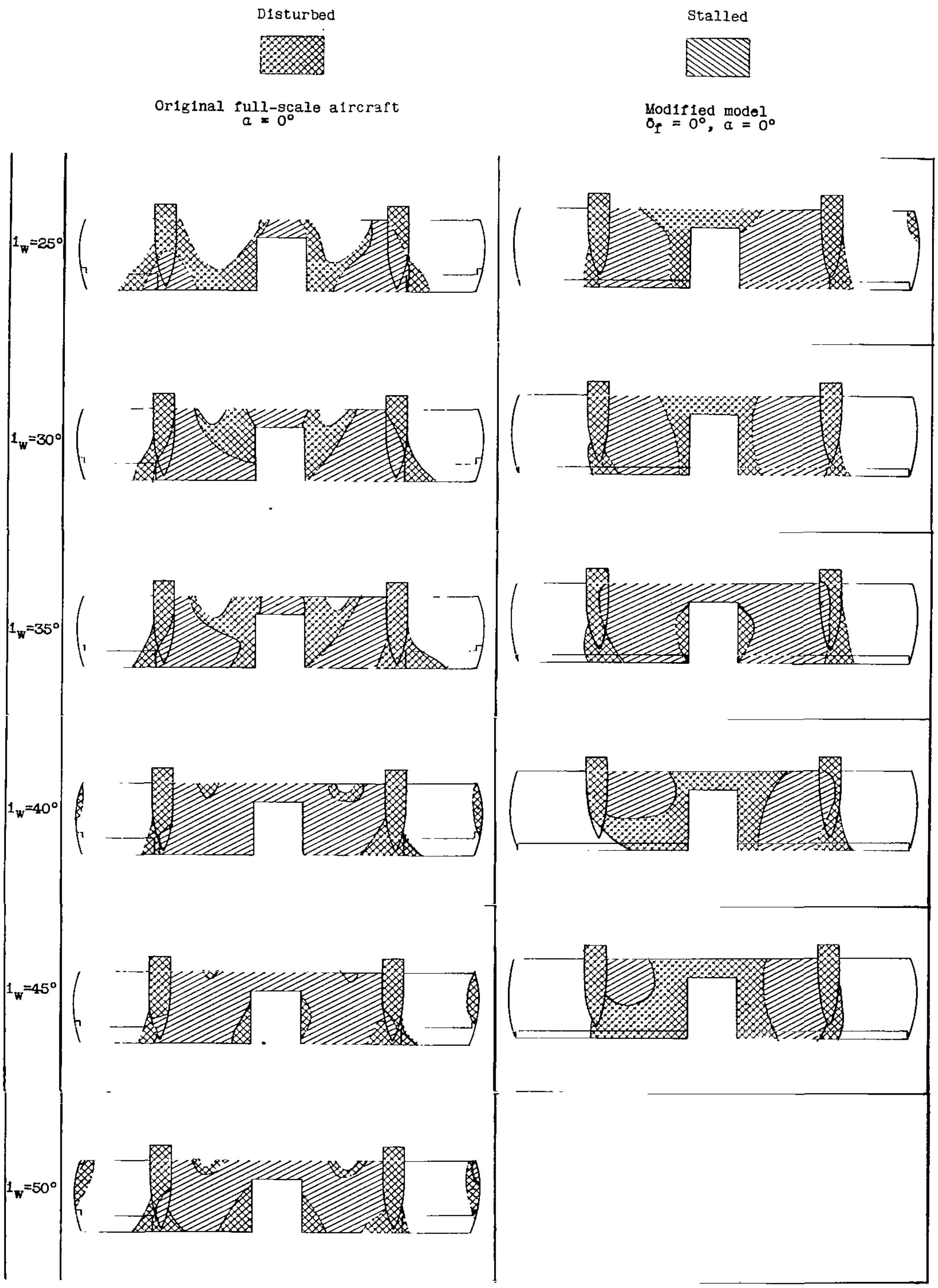
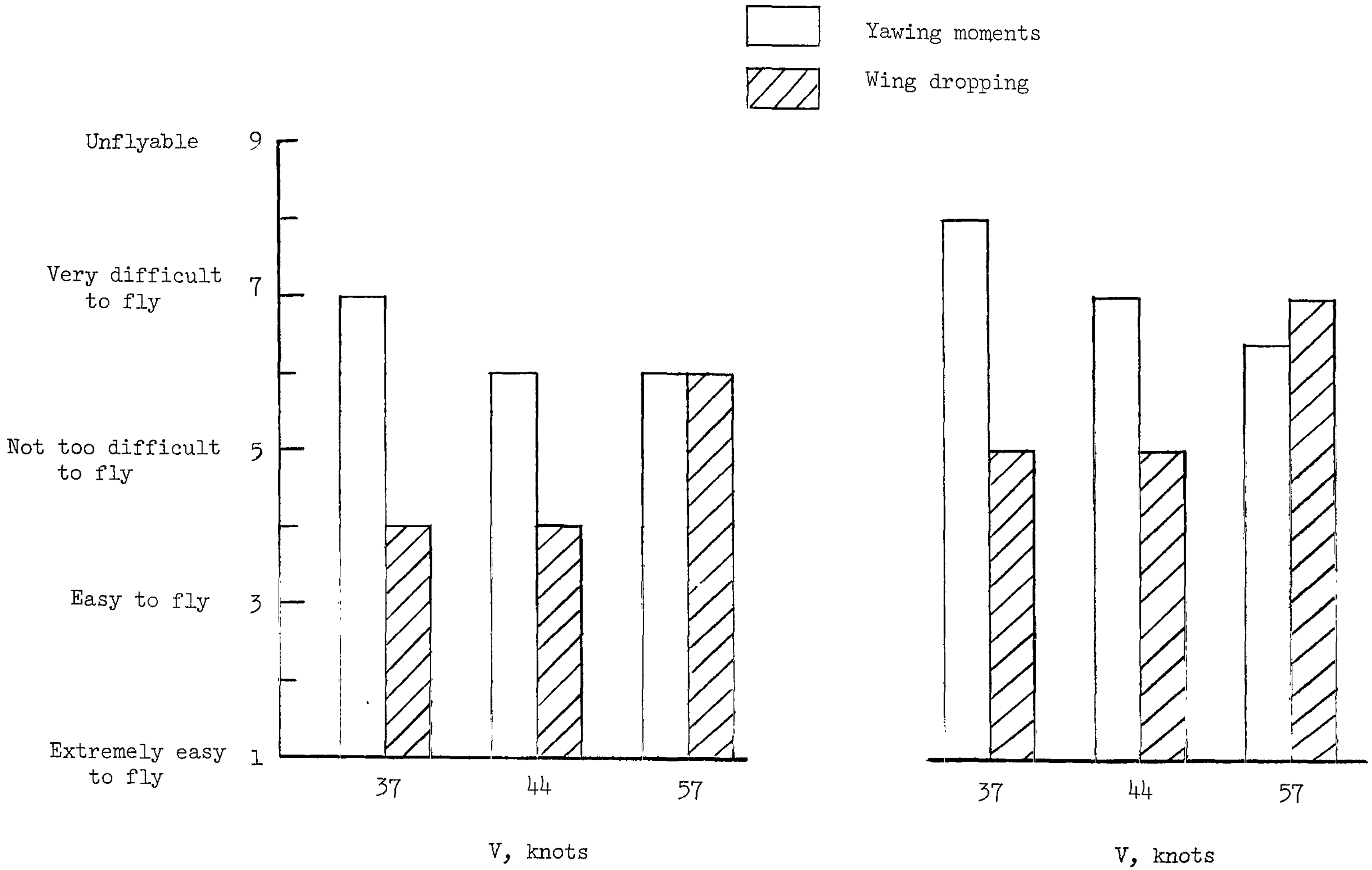


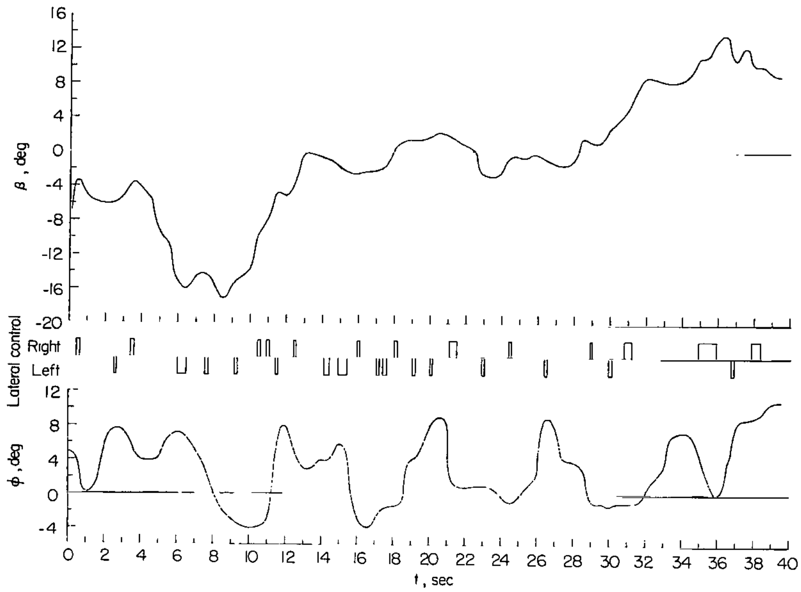
Figure 7.- Comparison of wing flow patterns between original full-scale VZ-2 (ref. 15) and present model.



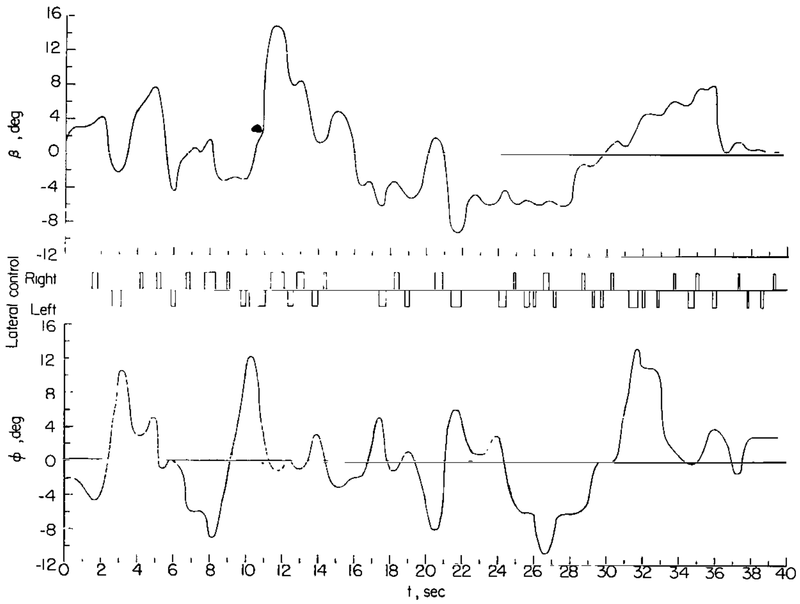
(a) Level flight.

(b) Descent flight.

Figure 8.- Pilot ratings of the wing-dropping and yawing tendencies for the flaps-retracted configuration.

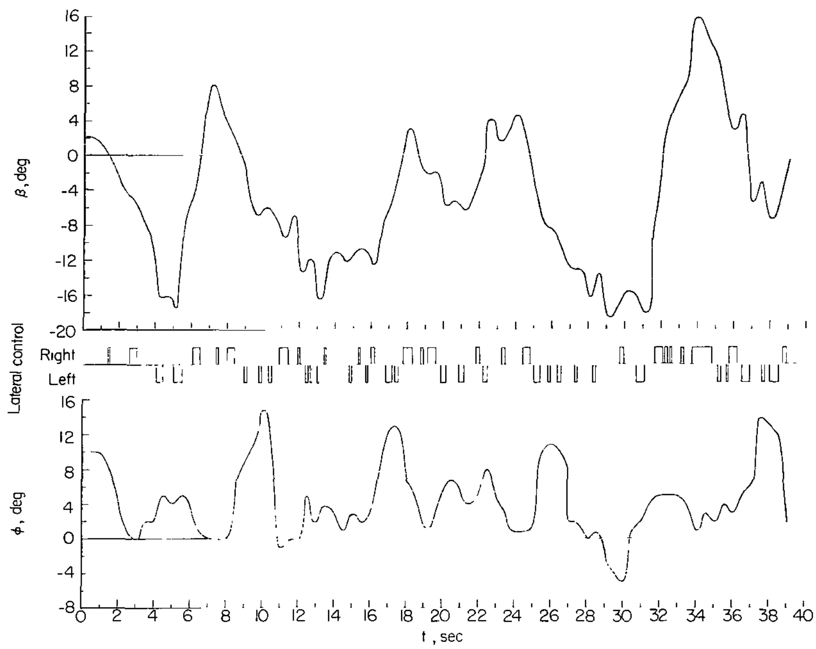


(a) V = 37 knots.

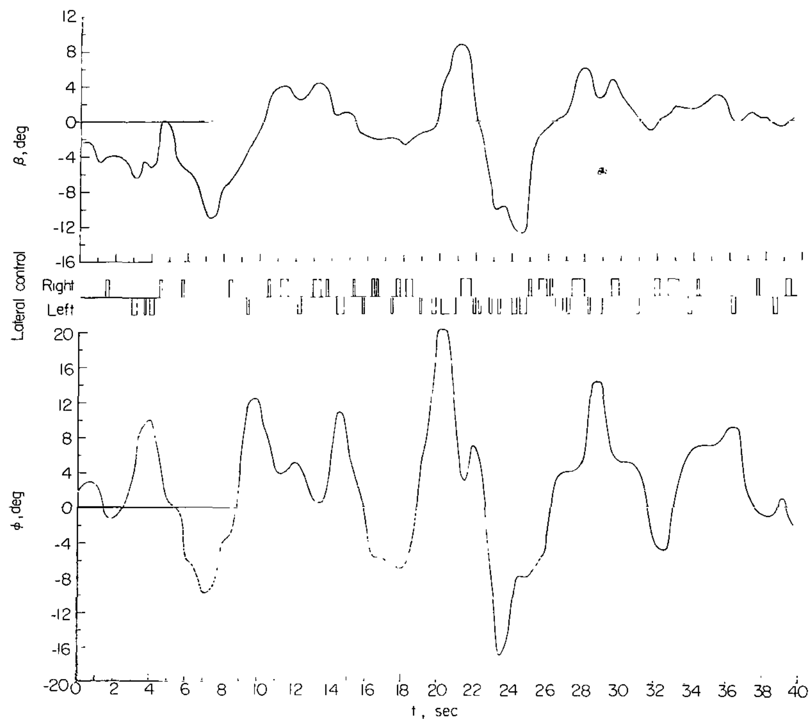


(b) V = 57 knots.

Figure 9.- Time histories of model motions. Flap-retracted configuration; level flight.

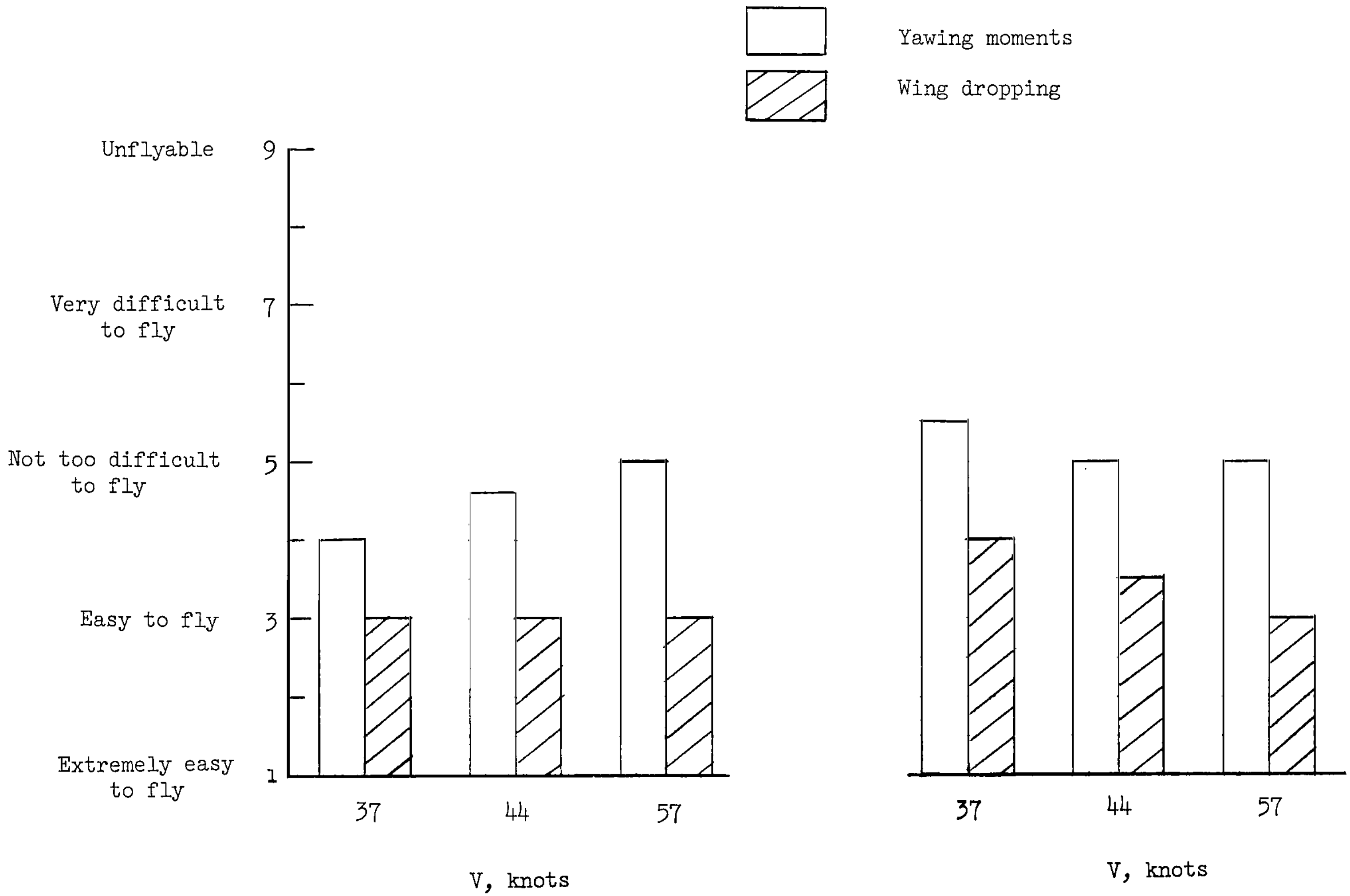


(a) V = 37 knots.



(b) V = 57 knots.

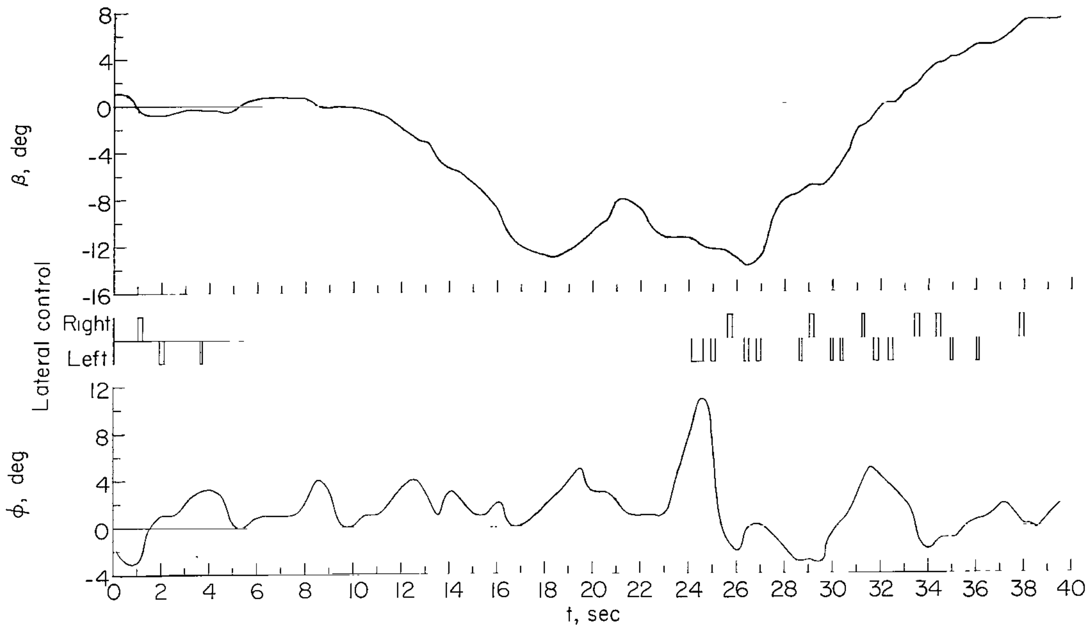
Figure 10.- Time histories of model motions. Flap-retracted configuration; descent flight.



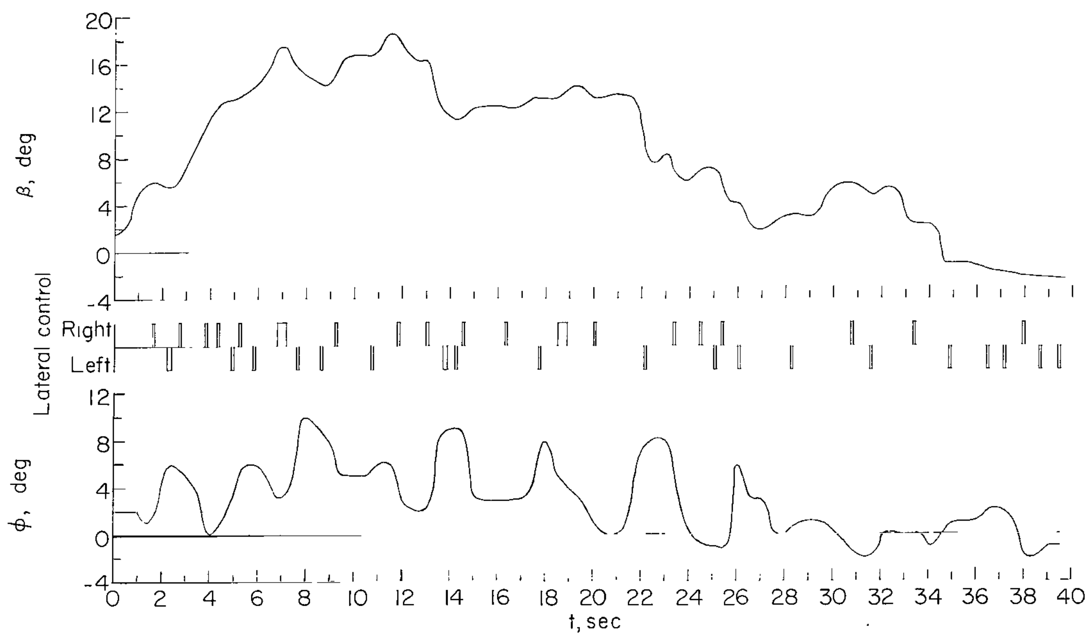
(a) Level flight.

(b) Descent flight.

Figure 11.- Pilot ratings of the wing-dropping and yawing tendencies for the model with a full-span slotted flap deflected 40°, and a full-span Krueger type nose flap.

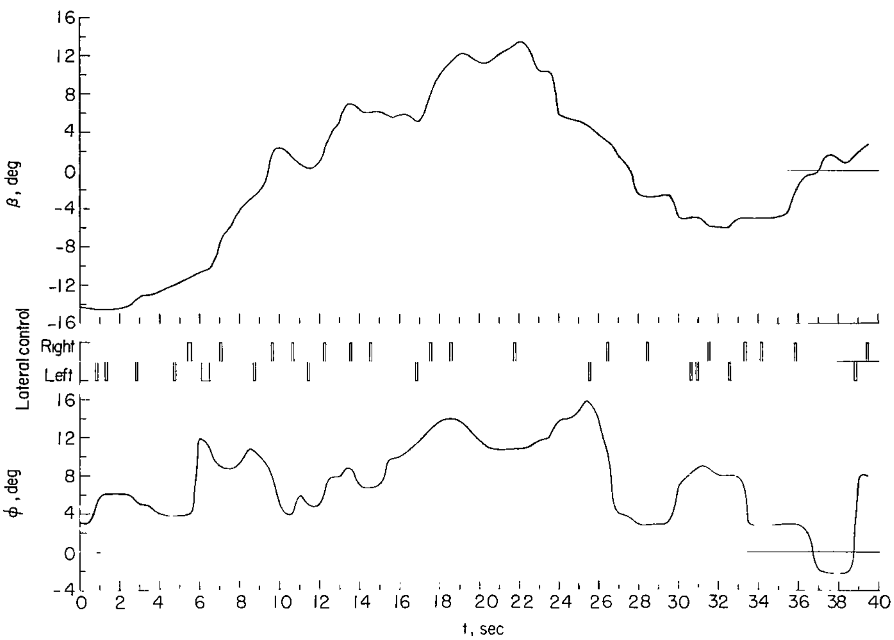


(a) V = 37 knots.

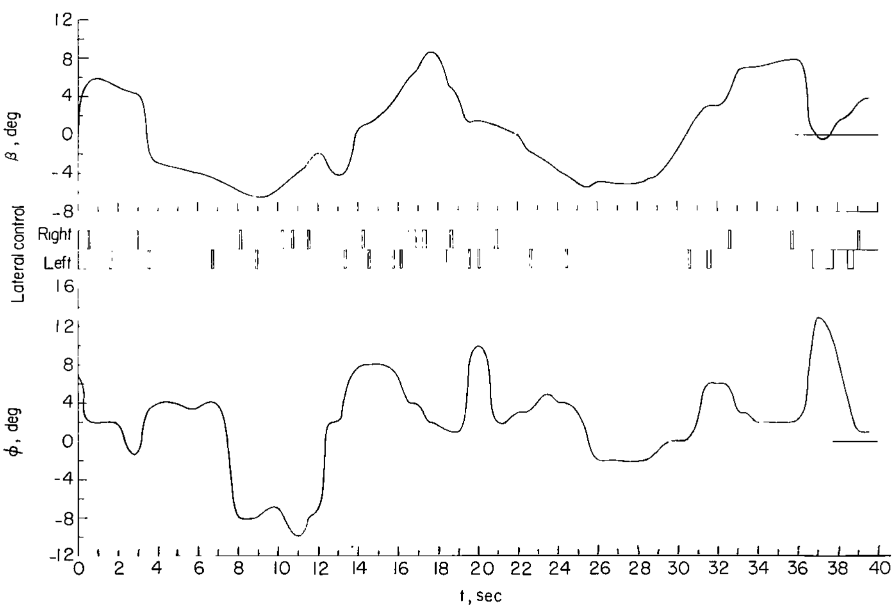


(b) V = 57 knots.

Figure 12.- Time histories of model motions. Full-span slotted flap deflected 40°; Krueger type nose flap; level flight.

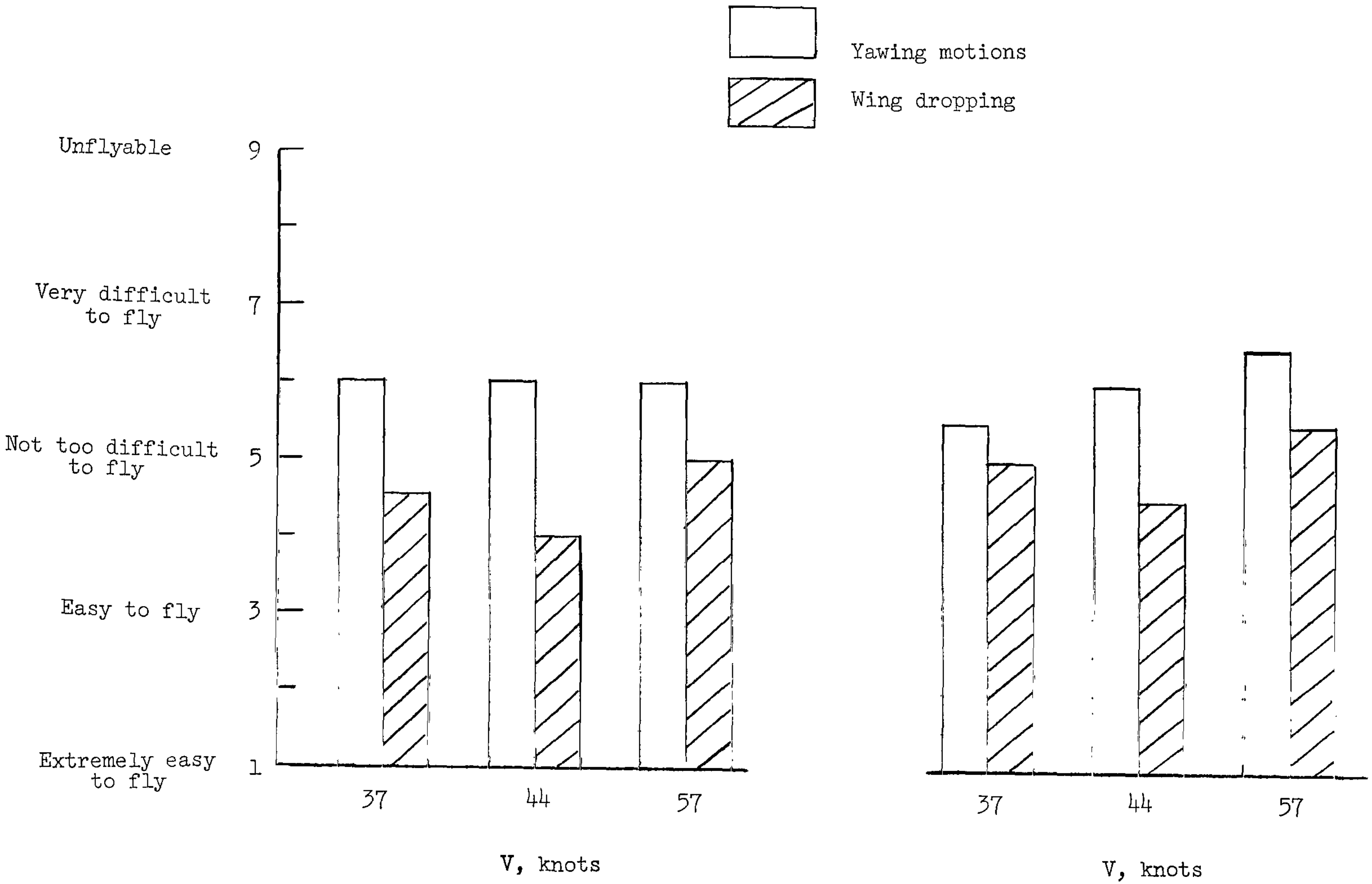


(a) V = 37 knots.



(b) V = 57 knots.

Figure 13.- Time histories of model motions. Full-span slotted flap deflected 40°; Krueger type nose flap; descent flight.



(a) Full-span slotted flap deflected 40°.

(b) Full-span Krueger type nose flap.

Figure 14.- Descent pilot ratings of the wing-dropping and yawing tendencies.

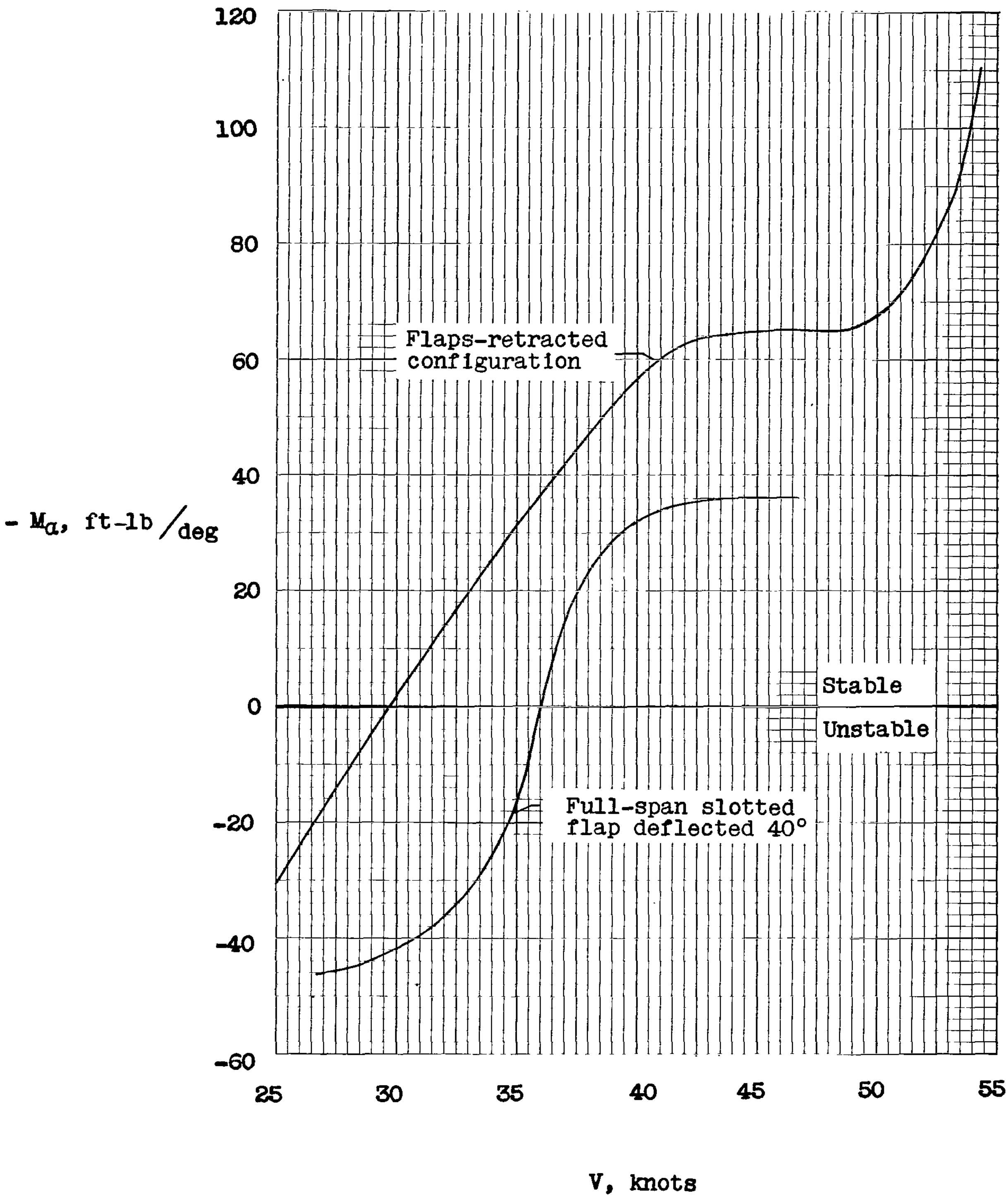


Figure 15.- Variation of the static longitudinal stability parameter with velocity.

2/7/85

"The aeronautical and space activities of the United States shall be conducted so as to contribute . . . to the expansion of human knowledge of phenomena in the atmosphere and space. The Administration shall provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

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